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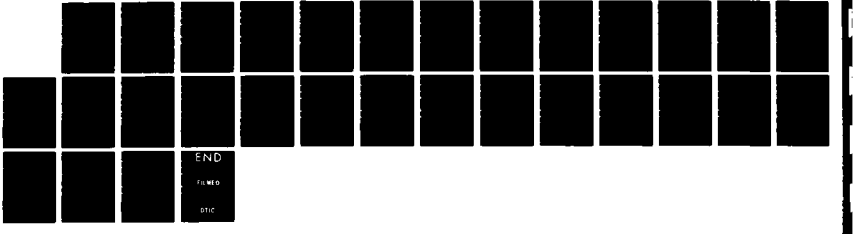

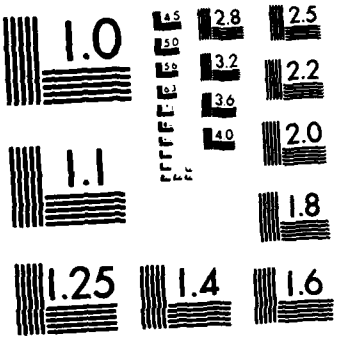

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short range order	NbN
long range order	inhomogeneous superconductors
superconductor	two dimensional superconductors
surface acoustic waves	localized electronic states
bulk waves	effective superconducting energy gap

(Over)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Surface waves propagating through NbN films which are columnar in nature and which therefore may behave like inhomogeneous two dimensional superconductors with localized electronic states show attenuation curves which yield an effective superconducting energy gap which saturates at about one third the usual value. A model has been proposed that ascribes this order parameter reduction to the localization of electronic states in the columnar regions.

(Over)

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20. Abstract - continued

The piezoelectrically induced attenuation curve in a superconducting NbN film is shifted by almost 5 K below the resistivity curve of the film. This shift may be attributed to the resistance in the cores of the Kosterlitz-Thouless vortex-antivortex flux pairs which may exist in an inhomogeneous superconductor.

A superconducting granular lead film has been investigated with surface acoustic waves propagating on the piezoelectric substrate. Most of the piezoelectrically induced attenuation in the normal state is quenched when the film becomes superconducting. The residual attenuation that remains in the superconducting state may be related to the fact that the surface acoustic wave samples the sheet resistivity of a small number of granules.

Bulk wave measurements have been performed on polycrystalline samples of $ErRh_4B_4$, $Er_{0.088}Ho_{0.912}Rh_4B_4$ and $Er_{0.4}Ho_{0.6}Rh_4B_4$.

19. Key Words - continued

piezoelectrically induced attenuation
Kosterlitz-Thouless
vortex-antivortex dipole
granular lead film
piezoelectric substrate
sheet resistivity
$ErRh_4B_4$
$Er_xHo_{1-x}Rh_4B_4$
BCS
superconducting energy gap
order parameter
lithium niobate
surface wave attenuation
fluctuations
ultrasonic attenuation coefficient
normal cores
700 MHz
interdigital electrodes
electron phonon interaction
Josephson Coupling
magnetic field
phonons
ferromagnetic phase transition
magnetization
staggered susceptibility
magnetization curves
$Er_{.088}Ho_{0.912}Rh_4B_4$
ferromagnetic state
mean field theory
$Er_{0.4}Ho_{0.6}Rh_4B_4$
ferromagnetic transition temperature
Er sublattice
He^3
H_{c1}
H_{c2}
Thermodynamic critical field
Magnetic Landau parameters
Superconducting Fraction
Superconducting Energy gap anomalies
re-entrant superconductor
Nb_3Sn
Chevrel phase superconductors
tin based ternary single crystals
ternary superconductors
$Cu_2Mo_6S_8$
layered superconducting films
array of Josephson coupled superconductors
Va_3Sn
Artifically produced superlattices
Amorphous molybdenum films
Nb
Zr
lead
mercury
heavy Fermion superconductors
superconducting quenching
Nb_3Ge

RESEARCH OBJECTIVES AND ACCOMPLISHMENTS

The objective of this research project was to initiate a program to study the interplay of short range order and long range order in superconductors using both surface acoustic waves and bulk waves.

Surface waves propagating through NbN films which are columnar in nature and which therefore may behave like inhomogeneous two dimensional superconductors with localized electronic states show an attenuation curve versus temperature in the superconducting temperature range which may be described by the superposition of a typical BCS attenuation curve and another curve which displays a maximum. These data may be placed in the BCS expression for the attenuation in order to deduce the temperature dependence of the superconducting energy gap or order parameter. The resulting curve follows the BCS energy gap temperature dependence up to a third of the value of the zero temperature energy gap and then it remains at this value for lower temperatures. Thus, it appears that the effective energy gap is reduced. A model has been developed which proposes that this order parameter reduction may be produced by the localization of electronic states in the columnar regions. The localization of the electronic states may broaden their energy levels. This may in turn reduce the energy gap which is effective for producing attenuation due to electron-phonon interaction.

An extremely large attenuation change is observed in one of the NbN films when it goes from the normal to the superconducting state. The normal state sheet resistivity of the film is about 30 KΩ/sq. The value of the attenuation change is too large,27 dB/cm, to be produced by electron phonon interaction. However since the film was deposited on a piezoelectric substrate, lithium niobate, a model has been proposed that ascribes this attenuation to piezoelectric coupling of the surface acoustic wave to the sheet resistivity of the film. In the normal state the attenuation is proportional to the sheet resistivity.

A model which uses the existence of Kosterlitz-Thouless vortex-antivortex dipoles is being proposed to describe the behavior of both the sheet resistivity and the surface wave attenuation below the superconducting transition temperature T_c. Above T_c the resistivity starts to decrease due to the fluctuations of the superconducting order parameter which are associated with a two dimensional second order phase transition. Below the superconducting transition T_c, the resistivity continues decreasing until it gets to zero at about 1/2 T_c. This is the value of the Kosterlitz Thouless transition temperature, T_{KT}. Below this temperature the vortex-antivortex dipoles are bound; and, therefore a dc current does not produce a net force on them, so they do not move and therefore do not contribute to the resistance. Above T_{KT}, the vortices are unbound and therefore are free to be moved by a Lorentz force and can contribute to the resistance.

The ultrasonic attenuation coefficient, however, does not follow the resistivity curve but remains constant down to about T_{KT}, and then it decreases smoothly to zero. According to our model, the attenuation in the superconducting state should be proportional to the fraction of the area which is occupied by the normal cores of the vortices regardless of their orientation. We have calculated the density of these dipoles as a function of temperature and computed theoretical curves which describe the temperature dependence of both the attenuation and the resistance of this film with the same set of parameters.

A granular lead film with a sheet resistivity of 1000 Ω/square was deposited between the interdigital electrodes of a lithium niobate 700 MHz surface acoustic wave device. Both the sheet resistivity and the ultrasonic attenuation coefficient were measured simultaneously in the superconducting temperature range of the film. There was rounding in both the attenuation and resistivity curves above the superconducting transition temperature, T_c.

Both sets of data are proportional to each other above T_c. Below T_c the resistance drops by two orders of magnitude and then gradually drops to zero at about 0.8 T_c. However the attenuation drops to about three tenths of its normal state value immediately below T_c, and then gradually goes to zero at about 0.3 T_c.

The value of the attenuation is too large, 4.4 db/cm, to be produced by electron phonon interaction. Again, it is proposed that this attenuation is produced by piezoelectric coupling to the sheet resistivity of the film. However, the attenuation in the normal state is twice as large as would be expected from the simultaneous measurement of the d.c. sheet resistivity and the attenuation coefficient. A model has been developed in collaboration with theorists at Technion University which provides qualitative agreement with the observed results. It is proposed that a d.c. electrical current measures the sheet resistivity of a sample whose dimensions encompass all the granules in the film. A surface acoustic wave measures the sheet resistivity of a sample whose dimensions are comparable to the acoustic wavelength, λ. It is postulated that this dimension is $\lambda/2\pi$. Such a length would contain only about sixteen grains. The average sheet resistivity both in the normal and superconducting states of such small samples is predicted to be higher than that for the whole sample by the use of percolation theory. Josephson coupling of the grains is assumed in the superconducting state. Qualitative agreement is found with the attenuation data in the superconducting state.

Bulk wave measurements were continued on the ternary ferromagnetic superconductor $ErRh_4B_4$ and initiated on $(Er_xHo_{1-x})Rh_4B_4$ superconductors.

Measurements on the ferromagnetic superconductor $ErRh_4B_4$ show maxima as a function of magnetic field at constant temperatures. The presence of the maxima may be described by the following model. Attenuation may be produced by the interaction of phonons with fluctuations associated with the ferro-

magnetic phase transition. This attenuation is proportional to the magnetization squared times the staggered susceptibility squared. At low fields the magnetization is linearly proportional to the magnetic field, saturating at higher fields, while the staggered susceptibility is only slightly affected by low fields and quenched by high fields. The product of these two quantities yields a maximum. In addition, as a function of temperature, for several constant applied magnetic fields, the attenuation also exhibits a maximum. These maxima may be viewed as magnetically shifted ferromagnetic transitions. Their position can be quantitatively evaluated from theoretical magnetization curves.

Measurements have been performed on a polycrystalline $Er_{0.088}Ho_{0.912}Rh_4B_4$ sample. This sample appears to have a ferromagnetic transition at $T_m = 6.2K$. The ultrasonic attenuation coefficient exhibits a maximum at 9.3 K. At temperatures below this maximum the attenuation is higher than at temperatures above this maximum. Thus the attenuation is higher in the ferromagnetic state than in the normal state. No evidence is obtained for a fluctuation peak in the attenuation at the ferromagnetic phase transition. This is in agreement with specific heat data which also does not display a peak at the transition. It thus appears that the phase transition for purely ferromagnetic $Er_xHo_{1-x}Rh_4B_4$ compounds can be described by a mean field theory without a contribution due to fluctuations.

Measurements have been performed using shear waves on a polycrystalline sample of $Er_{0.4}Ho_{0.6}Rh_4B_4$ which has a superconducting transition temperature $T_c = 6.7$ K and a ferromagnetic transition temperature $T_m = 3.5$ K. A drop in attenuation is observed immediately below T_m. This drop is associated with the quenching of spin fluctuations by the ferromagnetic state. In the superconducting state, the attenuation increases as the temperature is lowered. The increase in attenuation may be due to the appearance of fluctuations in the

Er sublattice. If a magnetic field is applied which is sufficient to remove superconductivity, the attenuation increase disappears.

A new He^3 probe has been designed and assembled. Preliminary ultrasonic measurements have been performed in it on an $ErRh_4B_4$ polycrystalline sample down to 0.8K. As expected, a peak in attenuation is found close to the temperature at which the sample undergoes a transition from the superconducting state to the ferromagnetic state.

PUBLICATIONS

1. Ultrasonic Attenuation Determination of H_{c1} and H_{c2} for $ErRh_4B_4$ at 1.5 K, S. Schneider, R. Chen, M. Tachiki, M. Levy, D. C. Johnston and B. T. Matthias, Solid State Communications 40, 61 (1981).

2. Thermodynamic Critical Field of Superconducting $ErRh_4B_4$ as a Function of Temperature, F. Behroozi, M. Levy, D. C. Johnston and B. T. Matthias, Solid State Communications 38, 515-519 (1981).

3. Experimental Determination of the Magnetic Landau Parameters in $ErRh_4B_4$, F. Behroozi, G. W. Crabtree, S. A. Campbell, M. Levy, D. R. Snider, D. C. Johnston and B. T. Matthias, Solid State Communications 39, 1041 (1981).

4. Superconducting Quenching of Piezoelectrically Induced Surface Wave Attenuation, H. P. Fredricksen, M. Levy and J. Gavaler, Proceedings of the 16th International Low Temperature Conference LT16, Physica 107, 113, (August-September 1981).

5. Ultrasonic Attenuation Study of $H_{c1}(T)$ for $ErRh_4B_4$, S. C. Schneider, M. Levy, M. Tachiki and D. C. Johnston, Proceedings of the 16th International Conference of Low Temperature Physics LT16, Physica, 107, 807, (August-September 1981).

6. Possible Ultrasonic Evidence for the Existence of Vortex-Antivortex Pairs, Hans P. Fredricksen, Moises Levy, Martin Ashkin and John Gavaler, Proceedings of the International Conference on Low Dimensional Conductors, Boulder Colorado, August 1981, Molecular Crystals and Liquid Crystals 79, 351 (1982).

7. Surface Acoustic Wave Determination of the Superconducting Fraction of a Nb_3Ge Film, Harry Salvo, Jr., Hans P. Fredricksen, Moises Levy and John Gavaler, Journal of Low Temperature Physics 48, 189 (1982).

8. Magnetic Free Energy of $ErRh_4B_4$ in Paramagnetic and Superconducting States, G. W. Crabtree, S. A. Campbell, S. Schneider, D. R. Snider and M. Levy, Journal of Low Temperature Physics 49, 73 (1982).

9. Ultrasonic Attenuation Determination of Superconducting Energy Gap Anomalies in Thin Films of NbN, H. P. Fredricksen, M. Levy, M. Tachiki, M. Ashkin and J. R. Gavaler, IEEE 1982 Ultasonics Symposium Proceedings, 1010 (82 CH 1823-4, Ed. B. R. McAvoy, IEEE, New York, 1982).

10. The Ultrasonic Attenuation of 700 MHz Surface Acoustic Waves in Thin Films of Superconducting NbN, H. P. Fredricksen, M. Levy, J. R. Gavaler, and M. Ashkin, Physical Review B27, 3065 (1983).

11. Superconducting Energy Gap Anomalies in NbN Films, H. P. Fredricksen, M. Levy, M. Tachiki, M. Ashkin, and J. R. Gavaler, Solid State Communications 48, 883 (1983).

12. Ultrasonic Attenuation Measurements of the Re-entrant Superconductor $Er_{0.4}Ho_{0.6}Rh_4B_4$, Keun J. Sun, Moises Levy, and M. Brian Maple, IEEE 1983 Ultrasonics Symposium Proceedings, 1087 (83 CH 1947-1, Ed. B. R. McAvoy, IEEE, New York, 1983).

13. Surface Acoustic Wave Investigation of Granular Lead Films, Hiroshi Tejima. Jeffrey Schmidt, Chris Figura, and Moises Levy, IEEE 1983 Ultrasonics Symposium Proceedings, 1100, (83 CH 1947-1, Ed. B. R. McAvoy, IEEE, New York, 1983).

14. Surface Acoustic Attenuation Granular Lead Films, Charles Kuper, Moises Levy, Michael Revzen, Amiron Ron and Boris Shapiro, 913, LT17, [U. Eckern, A. Schmid, W. Weber, H. Wuhl (eds.) Elsevier Science Publishers B. V., 1984].

15. Piezoelectric Attenuation of Surface Acoustic Waves by Bound Pairs of Vortex-Antivortex Dipoles in Superconducting Thin Films, Anders Schenstrom, Moises Levy, Hans Fredricksen and John Gavaler (to be submitted to *Physical Review*).

16. Ultrasonic Attenuation and Sensitive Transition in Superconducting Granular Lead Film, Charles Kuper, Michael Revzen, Amiron Ron, Boris Shapiro, Jeffrey Schmidt and Moises Levy (to be submitted to Physical Review).

TECHNICAL PERSONNEL

In addition to the principal investigator, the following technical personnel have worked on this grant. The university has supported some of them as part of their matching commitment.

Mr. Chris Figura	(Graduate Research Assistant - 2 yrs.) Preparation of surface wave devices for surface wave investigation of inhomogeneous granular superconductors and amorphous superconductors.
Dr. Hans Fredrickesn	(Graduate Research Assistant and Post Doc - 1-1/2 yrs.) Surface wave investigation of NbN.
Dr. Charles Kuper	(Visiting Professor - 4 months) Theoretical interpretation of measurements on $ErRh_4B_4$ and on thin films of NbN.
Mr. Guo Tai Lee	(Graduate Research Assistant - 1 yr.) Preparation of surface wave devices for surface wave investigation of NbN and inhomogeneous superconductors.
Ms. Ruby Chen Lee	(Graduate Research Assistant - 1 yr.) Ultrasonic Investigation of pure vanadium single crystals and ternary alloys.
Mr. Anders Schenstrom	(Graduate Research ASsistant - 1-1/2 yrs.) Surface wave investigation of inhomogeneous NbN films.
Mr. Jeff Schmidt	(Graduate Research Assistant - 3 yrs.) Preparation of surface wave devices for surface wave investigation of amorphous superconductors.
Dr. Susan C. Schneider	(Graduate Research ASsistant and Post Doc - 1 yr.) Ultrasonic investigation of superconducting ternary alloys and analysis of magnetization of $ErRh_4B_4$.
Mr. Keun-Jenn Sun	(Graduate Research ASsistant - 3 yrs.) Ultrasonic investigation of pure vanadium single cyrstals and ternary alloys.
Mr. Hiroshi Tejima	(Visiting Scholar sponsored by Brazilian Government - 3 yrs). Surface Wave Investigation of inhomogeneous superconductors.

Dr. Susan C. Schneider received her Ph.D. on May 17, 1981. Her thesis advisor was the principal investigator. The title of her thesis is "Ultrasonic Attenuation Study of the Re-entrant Superconductor $ErRh_4B_4$.

Dr. Hans P. Fredricksen received his Ph.D. on December 13, 1981. His thesis advisor was the principal investigator. The title of his thesis is "Ultrasonic Attenuation of Surface Acoustic Waves in Thin Films of High Transition Temperature Superconducting Nb_3Sn and NbN."

Dr. Hiroshi Tejima received his Ph.D. in September 1983 from the University of Sao Paulo in Sao Carlos, Brazil. The principal investigator was his thesis advisor. The title of his thesis is "Attenuation of Surface Acoustic Waves in Thin Granular Films of Superconducting Pb/PbO."

COUPLING

1. Nb_3Sn and Nb_3Ge Films

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration (continuing).

   c. Robert Hammond will attempt to deposit Nb_3Ge films on aluminum nitride substrates. He will also attempt to deposit Nb_3Sn and Nb_3Ge films on passivated lithium niobate substrates.

2. Niobium Nitride Films

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Collaboration and discussion (continuting).

   c. John Gavaler, Westinghouse Research Laboratory has deposited NbN films of different thicknesses on lithium niobate substrates. Eleven of these substrates have been measured and the data have been analyzed and are being reported.

3. Kosterlitz-Thouless Vortex-Antivortex Model

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration (continuing).

   c. Held continuing discussions with Martin Ashkin, Westinghouse Research Laboratory, concerning a vortex-antivortex model to interpret some of the data obtained from the ultrasonic surface wave measurements of the superconducting niobium nitride films prepared by John Gavaler.

4. Ternary Alloys

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration (continuing).

   c. Polycrystalline Samples of $Ho_xEr_{1-x}Rh_4B_4$ have been obtained from Brian Maple, U.C.-San Diego. These samples have a ferromagnetic transition temperature that is accessible with a He^4 cryostat. Therefore, the interplay of ferromagnetism with superconductivity can be more easily investigated ultrasonically.

5. Amorphous Superconductors

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration.

   c. Have obtained from Ted Geballe and Robert Hammond, Stanford University, amorphous molybdenum films stabilized with a small amount of niobium, which were deposited on quartz and lithium niobate substrates. Interdigital electrodes will be deposited on the substrates and preliminary measurements will be initiated.

6. Chevrel Phase Superconductors

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration.

   c. Powder samples of the Chevrel phase superconductors will be obtained from F. Fradin, Argonne National Laboratory, in order to determine if it is possible to propagate ultrasonic waves through them which will provide information about their superconducting energy gap and electron mean free path.

7. Tin Based Ternary Single Crystals

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration.

   c. Obtained from J. P. Remeika, Bell Laboratory, single crystals of tin based ternary single crystals that are both magnetic and superconducting. These crystals will permit the transmission of higher frequencies than in the polycrystalline ternary alloys. The frequency dependence of the attenuation coefficient should make it possible to distinguish between different models that have been proposed to explain the observed effects. Initial attempts at polishing the samples have shown them to be extremely brittle. New samples have been obtained from J. P. Remeika. A He^3 probe has been built and tested for these measurements.

8. Magnetization Curves of Ternary Superconductors

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration.

   c. Initiated a program of collaboration with George Crabtree, Argonne National Laboratory and Feredoon Behroozi, University of Wisconsin-Parkside, to measure the d.c. magnetization curves of the ternary superconductors.

9. Magnetization Curves of Superconductors

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration (continuing).

   c. Magnetization curves of ultrasonically measured vanadium single crystals have been obtained by Feredoon Behroozi, University of Wisconsin-Parkside.

10. Single Crystals of the Ternary Alloys

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration.

   c. Continued discussions with David Hinks, Argonne National Laboratory, concerning the possibility of obtaining single crystals of the ternary alloys. The first crystals will be of $ErRh_4B_4$. These crystals will also be measured with the He^3 probe.

11. Single Crystal of $Cu_2Mo_6S_8$

   a. Moises Levy, University of Wisconsin-Milwaukee.

   b. Discussion and collaboration.

   c. Continued discussions with Renee Flukiger, Solid State Institute, Karlsruhe, concerning the possibility of obtaining a single crystal of $Cu_2Mo_6S_8$ which he has already prepared.

12. Array of Josephson Coupled Superconductors

    a. Moises Levy, University of Wisconsin-Milwaukee.

    b. Discussion and collaboration.

    c. Continued the discussion with R. S. Newrock, University of Cincinnati, concerning the deposition of an array of Josephson coupled superconductors on a piezoelectric substrate. Interdigital electrodes will then be evaporated on this substrate in order to investigate the array with surface acoustic waves in the 700 MHz frequency range.

13. Artificially Produced Layered Superconducting Materials

    a. Moises Levy, University of Wisconsin-Milwaukee.

    b. Discussion and collaboration.

    c. Initiated discussions with Ted Geballe, Stanford University about the possibility of obtaining layered superconducting films of Nb and Zr in order to investigate them with surface acoustic waves.

14. Films of Va_3Sn

    a. Moises Levy, University of Wisconsin-Milwaukee.

    b. Discussion and collaboration.

    c. Initiated discussions with John Gavaler, Westinghouse, about obtaining thin films of which will be measured with surface acoustic waves. Two substrates covered with films have been obtained.

15. Artificially Produced Superlattice

    a. Moises Levy, University of Wisconsin-Milwaukee.

    b. Discussion and collaboration.

    c. Initiated discussions with Ivan Schuller and Cornell Chung, Argonne National Laboratories, about the possibility of obtaining superlattice made of Nb and Cu in order to investigate their characteristics with surface acoustics waves.

16. 1980 Applied Superconductivity Conference

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (September 20 - October 2, 1980, Santa Fe, New Mexico) and discussion.

c. A paper was presented

"Ultrasonic Surface Acoustic Wave Investigation of Thin Films of Superconducting NbN," Hans P. Fredricksen, Moises Levy, John Gavaler and Martin Ashkin.

Discussions were held with Martin Ashkin and Gohn Gavaler concerning the theoretical interpretation of the data obtained on the NbN films. Disucssed with Robert Hammond the possibility of obtaining Nb_3Sn films deposited on passivated $LiNbO_3$ substrates. Also discussed with him the possibility of obtaining amorphous molybdenum films stabilized with a small amount of Nb.

17. 1980 IEEE Ultrasonic Symposium

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (November 5-7, 1980, Boston).

c. Attended conference.

18. Westinghouse Research Laboratory Visit

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion (December 4, 1980).

c. Held discussions with Martin Ashkin concerning the Kosterlitz-Thouless vortex-antivortex model for explaining the excess surface wave attenuation in superconducting niobium nitride films.

19. Westinghouse Research Laboratory Visit

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion (March 4, 1981).

c. Continued discussions with Martin Ashkin concerning the model for explaining the excess attenuation in superconducting niobium nitride films. Started discussions with John Gavaler about obtaining films that are composed of alternating layers which are superconducting and insulating.

20. Ultrasonic Investigation of the Ferromagnetic superconductor $ErRh_4B_4$

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Lecture (March 6, 1981).

c. A lecture was given on this topic to the Physics Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania.

21. 1981 APS March Meeting

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (March 17, 1981).

c. A contributed paper was presented.

"Experimental Determination of Paramagnetic and Superconducting Free Energies of $ErRh_4B_4$," F. Behroozi, G. W. Crabtree, S. A. Campbell, D. R. Snider, M. Levy, and D. J. Johnston..

22. The Chemistry and Physics of Solids Gordon Conference

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (July 6-10, 1981, Plymouth, New Jersey).

c. Attended conference. Held discussions with Ted Geballe, Stanford, concerning the inhomogeneous superconducting film samples. Held discussions with John Gavaler concerning the ultrasonic measurement of NbN. Held discussions with Kazumi Maki (USC), H. Gutfrund (Racah Institute) and Art Freeman (Northwestern University) concerning the interpretation of the ultrasonic attenuation data obtained on the NbN superconducting films. Discussed the posssibility of obtaining a single crystal of a one dimensional organic conductor which shows a spin-density wave transition and another which shows a superconducting transition from K. Bechgaard, H. O. Oersted Institute, Copenhagen.

23. International Conferece on Low-Dimensional Conductors

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (August 10-14, 1981, Boulder Colorado).

c. A paper was presented.

"Possible Ultrasonic Evidence for the Existence of Vortex-Antivortex Pairs," Hans P. Fredricksen, Moises Levy, Martin Ashkin and John Gavaler.

24. 16th Low Temperature Physics Conference

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (August 19-26, 1981, Los Angeles, California).

c. Two papers were presented.

"Superconducting Quenching of Piezoelectrically Induced Surface Wave Attenuation," H. P. Fredricksen, M. Levy and J. Gavaler.

"Ultrasonic Attenuation Study of $H_{c1}(T)$ for $ErRh_4B_4$,"
S. C. Schneider, M. Levy, M. Tachiki and D. C. Johnston.

25. 1981 IEEE Ultrasonics Symposium

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (October 14-17, 1981).

c. Attended conference, chaired a session and presented a paper. "Electron-Phonon SAW Attenuation of Nb_3Sn on $LiNbO_3$," S. C. Schneider, H. P. Fredricksen and M. Levy.

26. Energy Conversion Devices Laboratory Visit

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion and collaboration (Nov. 20, 1981).

c. Initiated discussions with Frank Missel concerning the possibility of obtaining films of amorphous superconductors on piezoelectric substrates in order to measure their properties with surface acoustic waves. Two samples have been obtained and preliminary measurements have been made.

27. Ultrasonic Investigation of the Ferromagnetic Superconductor $ErRh_4B_4$

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Lecture (March 29, 1982).

c. A lecture was given on this topic to the Physics Department, University of Toronto, Toronto, Canada.

28. Visit to Instituto Venezolano de Investigaciones Cientificas (Venezuelan Institute of Scientific Research)

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquia and discussion.

c. Gave seven different colloquia to the Physics Department and the Electrical Engineering Department.

1. Electron Phonon Interaction - June 10, 1982.
2. Ultrasonic Attenuation in Type I and Type II Superconductors - June 11, 1982.
3. Ultrasonic Investigation of the Magnetic Superconductor $ErRh_4B_4$ - Part I - June 14, 1982.
4. Ultrasonic Investigation of the Magnetic Superconductor $ErRh_4B_4$ - Part II - June 16, 1982.
5. Surface Acoustic Wave Measurements of Superconducting Films of Al and Nb_3Ge - June 18, 1982.
6. Surface Acoustic Wave Measurements of Superconducting Films of Nb_3Sn and NbN - June 21, 1982.
7. Giant Interaction Between Surface Acoustic Waves and Ferromagnetic Nickel Films - June 23, 1982.

Discussed with Dr. Romer Nava and Dr. Marcos Rodriguez, Physics Department, measurements on the thin film superconductors. Also discussed with Dr. Miguel Octavio, Electrical Engineering Department, the measurements on NbN superconducting films.

29. Josephson Coupled Superconducting Arrays - Visit to Physics Departments at the University of Cincinnato and Ohio State University (July 6, 1982)

a. Moises Levy, University of Wisconsin-Milwaukee

b. Discussion and collaboration.

c. Visited the Physics Department, University of Cincinnati and the Physics Department, Ohio State University in order to initiate a collaboration and discussion with R. S. Newrock, Physics Department University of Cincinnati and Dr. J. C. Garland, Physics Department, Ohio State University. Dr. Newrock will photolighographically produce the pattern of an array of Josephson coupled superconductors on a piezoelectric substrate. Dr. J. C. Garland will then evaporate the array. After these are prepared, interdigital electrodes will be deposited on the substrate and surface acoustic wave measurements will be made on the films.

30. Visit to the Research Institute for Iron, Steel and Other Metals, Tohoku University, Sendai Japan (August 20 - September 5, 1982)

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion and collaboration.

c. Discussed with Professor Masashi Tachiki the surface acoustic wave measurements on superconducting NbN films. A tentative simplified model wherein strong localization of the normal electrons may explain the observed effects was developed. Also discussed with him the measurements on $ErRh_4B_4$ in the absence of an applied magnetic field. It is possible that the maximum in ultrasonic attenuation observed in the superconducting phase may be attributed to a relaxation mechanism associated with the two lowest magnetic energy levels of this ferromagnetic superconductor. Also discussed the possibility of obtaining single cyrstals of ferromagnetic superconductors.

31. International Conference on Magnetism 1982

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference, Kyoto, Japan (September 6-10, 1982).

c. Attended conference.

32. The 10th International Colloquium on Magnetic Films and Surfaces

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference, Yokohoma, Japan (September 13-16, 1982).

c. Presented an invited paper

"Giant Attenuation of Surface Acoustic Waves by Ferromagnetic Films."

33. 1982 IEEE Utrasonic Symposium

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (October 27-29, 1982, San Diego, CA).

c. Attended conference, chaired session and presented a paper "Ultrasonic Attenuation Determination of Superconducting Energy Gap Anomalies in Thin Films of NbN," H. P. Fredricksen, M. Levy, M. Tachiki, M. Ashkin, and J. R. Gavaler.

34. Materials Research Society 1982 Annual Meeting

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (November 1-4, 1982, Boston, MA).

c. Attended conferene. Discussed the possibility of obtaining new single crystals of the tin based ternary magnetic superconductors with J. P. Remeika, Bell Laboratory. Discussed the NbN data and analysis with Martin Ashkin, Westinghouse R & D. Discussed the possibiity of making surface acoustic wave measurements on intercalated compounds with M. S. Dresselhaus, MIT.

35. March Meeting of the American Physical Society

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference and discussion (March 21-25, 1983).

c. Attended conference and presented paper

"Residual Piezoelectrically Induced Attenuation Produced by Flux Pairs in a Granular Pb-PbO_x Film," Hiroshi Tejima, Jeffrey Schmidt, Chris Figura, and M. Levy.

Discussed with Ted Holstein, R. Meservey, David Paul, Walt Thomash, Art Hebard, Ken Grey and Alan Goldman measurements made on granular Pb-PbO_x films.

36. Visit to Argonne National Laboratory

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquium and discussion (April 26, 1983).

c. Gave the following colloquium to the Materials Science Group "Ultrasonic Investigation of Superconducting Ferromagnets", also discussed with George Crabtree and David Hinks the possibility of obtaining a single crystal of $ErRh_4B_4$.

37. Visit to Northwestern University

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquium and discussion (April 27, 1983).

c. Gave the following colloquium to the Physics Department "Surface Acoustic Wave Investigation of Superconducting Films."

Discussed with John Ketterson techniques for making surface acoustic wave measurements.

38. Gordon Research Conference

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference and discussion (July 4-15, 1983).

c. Attended conference on Chemistry and Physics of Solids. Discussed with Ted Geballe possibility of obtaining layered superconducting films of Nb and Zr in order to investigate them with surface acoustic waves.

39. Argonne National Laboratory Workshop

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Workshop and discussion (August 1-2, 1983).

c. Participated in workshop and presented paper "Ultrasonic Attenuation Measurements of the Re-entrant Superconductor $Er_{0.4}Ho_{0.6}Rh_4B_4$." Keun-Jen Sun, Moises Levy and Brian Maple.
Discussed with David Hinks and George Crabtree their attempts for producing single crystals of $ErRh_4B_4$ and the information that ultrasonic measurements could provide.

40. Visit to University of Sao Paulo, Sao Paulo, Brazil

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion (August 9-11, 1983).

c. Discussed with Frank Missel techniques for measuring amorphous superconducting strips with surface acoustic waves.

41. Visit to Federal University at Sao Carlos, Brazil

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquium and discussion (August 18, 1983).

c. Gave the following colloquium at the Physics Department "Giant Attenuation of Surface Acoustic Waves by Ferromagnetic Films."
Discussed with the faculty there, the possibility that some of them would spend sabbatical leaves at UWM to work on the surface wave investigation of superconducting films, platelets and strips.

42. Visit to University of Sao Paulo in Sao Carlos, Brazil

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquium and discussion (August 19, 1983).

c. Gave the following colloquium at the Physics Department "Ultrasonic Attenuation in the Ferromagnetic Superconductor $ErRh_4B_4$."
Discussed ultrasonic measurements being performed on chromium crystals to which different amounts of vanadium had been added.

43. Visit to University of Campinas, Sao Paulo, Brazil

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquium and discussion (August 22, 1983).

c. Gave the following colloquium at the Physics Department "Ultrasonic Attenuation in Thin Film Superconductors."
Discussed with Dr. Cerdeira measurements of ultrasonic attenuation near the upper critical field of very pure type II superconductors.

44. Visit to University of Cincinnati

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion and collaboration (September 22, 1983).

c. Visited the Physics Department in order to discuss with Dr. R. S. Newrock and his research assistant Mr. Ken Brown the design of the surface acoustic wave device that will be used to measure the array of Josephson coupled superconductors which they will deposit on the substrate of the device.

45. IEEE 1983 Ultrasonics Symposium

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference (Oct. 31, Nov. 1-2, 1983, Atlanta, GA).

c. General Chairman of conference. Presented two papers "Surface Acoustic Wave Investigation of Granular Films," Hiroshi Tejima, Jeffrey Schmidt, Chris Figura, and Moises Levy. "Ultrasonic Attenuation Measurements of the Re-Entrant Superconductor $Er_{0.4}H_{0.6}Rh_4B_4$, Keun J. Sun, Moises Levy and M. B. Maple. Held discussions with John Ketterson concerning dilution refrigerators.

46. Visit to Technion University

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Colloquium, Seminar, discussion and collaboration (Nov. 20, 1983 to Feb. 20, 1984).

c. Gave a colloquium on "Surface Acoustic Wave Investigation of Superconducting Films," December 15, 1983.
Gave a seminar on "Interaction of Ferromagnetic Films With Surface Acoustic Waves," December 20, 1983.
Initiated discussions with Boris Shapiro, Charles Kuper, Michael Revzen, and Amiron Ron, theorists in the Physics Department at the Technion, about the surface acoustic wave data obtained on granular lead films. A model was developed to explain the discrepancy between the d.c. resistance of a granular film and the apparent resistance deduced from surface acoustic piezoelectric coupling to the local sheet resistance of the film. A paper is being prepared for publication. A short paper was presented at the 17th

International Low Temperature Conference. Initiated discussions with Charles Kuper, Michael Revzen and Jozy Ashkenazy about the anomalously large change in ultrasonic attenuation that is observed for pure single crystals of niobium, lead and mercury close to the superconducting transition. This anomaly disappears in impure crystals of these superconductors. A preliminary model that ascribes this discrepancy to the fact that the energy gap in the superconducting state may round out the sharp features of the Fermi surface in a pure metal is being investigated.

47. Visit to Tel Aviv University

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Seminar and discussion (January 19, 1984).

c. Gave a seminar on

"Surface Acoustic Wave Investigation of Superconducting Films."

Held discussions with Guy Deutsche, Joseph Imry, and David Bergman about the theoretical interpretation that was developed at the Technion to describe the experimental results obtained on a granular lead film.

48. Visit to Ben Gurion University, Beer Sheva

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Seminar and discussion (January 26, 1984).

c. Gave a seminar on

"Surface Acoustic Wave Investigation of Superconducting Films."

Saw Professor Gady Goroditsky's lab and talked to his technician about surface acoustic wave techniques. Discussed localization in thin films with Dr. Obadia.

49. Visit to Hebrew University, Jerusalem

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Seminar and discussion (January 31, 1984).

c. Gave a seminar on

"Ultrasonic Investigation of the Ferromagnetic Superconductor $ErRh_4B_4$."

Visited Professor Avram Many's surface studies group. Dr. Yehuda Goldstein described in detail their new enhanced surface Raaman apparatus.

50. March Meeting of the American Physical Society

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference and discussion (March 23-30, 1984).

c. Attended conference and chaired session on "Superconducting Materials." Disucssed with J. L. Smith, Los Alamos Nat. Lab. and H. Ott, ETH, Zurich, possibility of obtaining single crystals of the heavy Fermion superconductors. Discussed with John Ketterson, George Crabtree and David Hinks, Argonne National Labs, possibility of obtaining single crystals of the heavy Fermion superconductors. Continued discussions with George Crabtree and David Hinks about obtaining their single crystals of $ErRh_4B_4$. Discussed with Horst Stormer the possibility of obtaining a GaAs-GaAlAs hetero-structure which displays the fractional Hall effect for experiments which couple the piezoelectric fields of a surface acoustic wave to the Hall resistance of a two dimensional electron gas. Continued discussions with Rick Newrock concerning the possibility of obtaining the arrays of Josephson coupled superconductors.

51. Gordon Research Conference

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Conference and discussion (July 23-27, 1984).

c. Attended conference on Quantum Solids. Continued discussions with Ted Geballe about the possibility of obtaining layered superconducting films of Nb and Zr in order to investigate them with surface acoustic waves. Obtained GaAs-GaAlAs heterostructure structure from Horst Stromer, Bells Labs. Discussed with Mel Pomerantz percolation model proposed for explaining anomalous acoustic surface wave attenuation in granular superconducting lead film.

52. Westinghouse Research Laboratory Visit

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion (July 31, 1984).

c. Continued discussions with John Gavaler, about measuring thin films of Va_3Sn with surface acoustic waves. Obtained two more samples from him.

53. Group of Sonics and Ultrasonics

a. Moises Levy, University of Wisconsin-Milwaukee.

b. Discussion.

c. Member of the program committee for the 1980, 1981, 1982, and 1983 IEEE Ultrasonics Symposia. Member of the 1980-1983 Administrative Committee of the Group of Sonics and Ultrasonics and General Chairman of the 1983 IEEE Ultrasonics Symposium.

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